HISTORY 107
History of the Physical Sciences

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T,TH 9:00 - 10:15 AM – ARC 1008
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Office Hours: M,W: 12:30 – 1:30 PM

Description

From the catalog: Study of the development of the major physical laws currently used in describing our physical world. Some considerations of the influences of these developments on other areas of knowledge and on society in general. Cross Listed: PHSC 107 (only one may be counted for credit). General Education Area B (B5).

Intended audience: This course is designed for any 2nd – 4th year student interested in understanding the conceptual foundations of modern science, and the historical evolution of these foundations.

The course in more detail: In recent decades, the physical sciences and the technologies borne of them have become so highly formalized and proprietary that it is often the case that even professional scientists have little understanding of fundamental scientific theories beyond the scope of their own specialties. Thus, as our worldview becomes more and more centered upon science and technology, the average person is ironically expected to understand less and less about that worldview. One might therefore anticipate that as science continues to evolve, our engagement of it will likely steadily drift more and more toward passive, uncritical inheritance rather than active participation. But the history of the evolution of our current scientific worldview reveals a very different story—one where it is not only the science that drives the worldview, but also one in which the worldview drives the science.

In this course, we will study the historical evolution of the intuitive (i.e., in the Greek sense of careful koinos nous or careful ‘common sense’--classically logically reasonable) conceptual foundations of modern physics, including the special and general theories of relativity and the latest interpretations of quantum mechanics. We will trace this evolution from its origins in ancient natural philosophy, through the medieval and early modern periods and the Enlightenment, up to the present day.

Within the discipline of history, this course falls within the framework of the history of ideas—a field of research in history that deals with the expression, preservation, and evolution of ideas. The history of ideas is a central component of the discipline of intellectual history. Intellectual history refers to the historiography of ideas and thinkers, and, as practiced by historians, can include the history of philosophy and the history of science.

Outcomes

• an understanding of the history of science and technology and the evolution of the conceptual foundations of modern science from its early roots in ancient Greek philosophy.

• an understanding of the most important sources for the study of the history of the physical sciences.

• an understanding of foundational scientific questions that remain unsettled today, the historical roots of these questions, and the historical evolution of scientific thought aimed at their answer.
• the ability to understand the ways in which history has informed, and continues to inform, the evolution of scientific progress from the ancient period to the present day.

• the ability to apply historical knowledge of the origins and evolution of modern science, gained via the above 4 areas of understanding, to a critical evaluation of contemporary scientific claims.

• the ability to critically evaluate and employ literary and material evidence in studying the history of science and its evolution from Greek philosophy of nature and mathematics.

• GE Area B (B5) Outcomes: This course will • Develop an understanding of the principles underlying and interrelating natural phenomena including the foundations of our knowledge of living systems. • Introduce students to one or more of the disciplines whose primary purpose is to acquire knowledge of the physical universe rather than merely to apply existing knowledge. • Develop an appreciation of the methodologies of science, the requisite features of scientific endeavors, and the limitations of scientific inquiry. Students will be able to: • Demonstrate a knowledge and understanding of natural phenomena. • Apply the methodologies of science when approaching a scientific problem. • Explain the limitations of scientific inquiry.

Requirements

Our work will primarily be lecture and discussion, so both careful attention to the readings and class participation will be crucial for a lively course. Always bring your texts to class.

EXAMINATIONS AND PAPERS

There will be two examinations--one take-home mid-term and one final. There will be one 6-8 page paper. All due dates are given in the reading and lecture schedule below.

ATTENDANCE

It is impossible to succeed in this course if you miss the lectures. To encourage attendance, students are permitted only 2 unexcused absences.

Note: Anyone who misses 2 lectures in the first 2 weeks of class will be administratively dropped to make room for serious students who are attempting to add.

PHONES AND COMPUTERS

Phones, laptops, tablets, and all other electronic multi-media devices are NOT permitted in class. Please refer to my colleague Dr. Merlino's excellent explanation: (www.csus.edu/indiv/m/merlinos/noLaptops.html).

POWERPOINT PRESENTATIONS AND PRE-OUTLINED LECTURES

I do not use these in my courses (other than for the occasional diagram, table, graph, or some other image of this kind.) The ability to listen attentively to a lecture or discussion, follow its structure, identify its key points, and take proper notes, is crucial. If this is done for you via Powerpoint slides, or lecture outlines (whether pre-distributed or written on the chalkboard), you are denied the opportunity to exercise and strengthen this ability, or develop it in the first place if you haven't already. It is not difficult, but requires effort. Whatever your intended profession, this is an ability that you will need, and one that many employers lament is deficient or even non-existent in recent college graduates.

**Texts and Materials**

- Edward Grant. *A History of Natural Philosophy: From the Ancient World to the Nineteenth Century*. Cambridge: Cambridge University Press, 2007 (Text designated as ‘HNP’ in reading schedule.)
  
  Average cost new: $22, used $15

  
  Average cost new: $9, used $5

  
  Average cost new: $9, used $1.50

- Readings downloaded from course website / SacCT (Designated as ‘D’ in reading schedule.)

**Grading**

Class participation: 15% 3 or more unexcused absences results in 0%

Paper: 25% No late work is accepted.

Mid-term exam: 25%

Final exam: 35%

**A-level work:** All students begin this course with an A. In order to maintain it, all written work (paper, mid-term, and final exams) must exhibit complete, well-argued responses to the questions asked. This requires reference to the readings and lectures. For this reason, on-time attendance of all lectures and completion of all scheduled readings are requirements for success in this course.

**Academic Standards:** All sources in papers must be cited and given appropriate credit. The author of any information from the Internet must be given credit; using such information without indicating the source constitutes plagiarism, as it would with print publications. Students are allowed to discuss lectures and even assignments with each other, but they must do their own work. Students are required to read the University policy on academic honesty, which can be found here: [www.csus.edu/umanual/AcademicHonestyPolicyandProcedures.htm](http://www.csus.edu/umanual/AcademicHonestyPolicyandProcedures.htm)
A 93-100% Excellent work
A- 90-92% Nearly excellent work
B+ 87-89% Very good work
B 83-86% Good work
B- 80-82% Mostly good work
C+ 77-79% Above average work
C 73-76% Average work
C- 70-72% Mostly average work
D+ 67-69% Below average work
D 60-66% Poor work
F 0-59% Failing work

Students with Disabilities: If you have a documented disability and require accommodation or assistance with assignments, tests, attendance, note taking, etc., please see the instructor during the first week of the semester so that appropriate arrangements can be made to ensure your full participation in class. Also, you are encouraged to contact the Services for Students with Disabilities (Lassen Hall) for additional information regarding services that might be available to you.

Reading and Lecture Schedule

Week 1: Introduction
8/28, 30

- The role of history in the evolution of science, and the study of the ways in which scientific theories are at once conditioned by and conditioning of the conventional worldviews from which the theories derive. Likewise, scientific theories are at once conditioned by and conditioning of the fundamental presuppositions and first principles from which these conventional worldviews derive.

- The ways in which scientific ‘paradigms’ mediate this reciprocal conditioning.

Readings: Kuhn [SSR], Chapters 1-5 (pp. 1-51)

Week 2: Why studying history and philosophy of science is especially important today
9/4, 6

- The increasing centrality of science and technology in society, and the ways in which popular disseminations of science often mask underlying tensions (and sometimes fundamental incompatibilities) between competing paradigms. Examples include the Standard Model of particle physics compared to the Standard Model of cosmology, the related incompatibility of quantum mechanics and the general theory of relativity, etc.

- A closer look at the latter as a case study of clashing paradigms: The physics of the very large vs. the physics of the very small, the incompatible conceptual presuppositions of each, and the popular portrayal of each as exhibiting the fundamental character of the natural world, despite their incompatibility.

- The ways in which increasingly specialized and increasingly abstract conceptual formalisms give popular disseminations of modern science the character of truths revealed via authority, rather than truths that can be reasoned by the common person. In what ways is this an historical regression from the Enlightenment theme of autonomy via reason back to the medieval theme of heteronomy via authoritative revelation?
Readings:

Bacon, excerpts from the *New Organon* [D]


Week 3: *The Beginnings of Western Science*

9/11, 13

- The historical, philosophical, and practical evolution of modern science from its roots in ancient natural philosophy.

- Preliterate origins.

- Ancient Egypt and Mesopotamia.

- Pre-Socratic Hellenic natural philosophy and medicine.

Readings: [HNP] 1-21

Week 4: *Plato*

9/18, 20

- His attempt to relate seemingly incommensurable cosmological paradigms—those grounded in nature’s necessary features (viz. logical and mathematical conceptual relations) with those grounded in nature’s contingent features (viz. causal physical relations). As we will see throughout the remainder of this course, in many ways, the history of science is fundamentally a history of attempts to discover the true nature of the relationship between logic and causality (cf. the Krauss readings from Week 2 re: the relationship between mathematical and physical structure in modern cosmology.)

- His critique of the reductive-deductive analysis of wholes into parts —i.e., the presumption that a fundamental understanding of the whole derives from the fundamental understanding of the most fundamental part.

Readings: [HNP] 21-26; Plato, excerpts from *Theaetetus* [D]; excerpt from *The Republic*, Book VI [D].

Week 5: *Aristotle*

9/25, 27

- His proposed bridging of the chasm that Plato believed separated the order of causal relation (what appears to be) from the order of logical implication (what is reasoned to be).

- An overview of Aristotle’s life and works, and the historical preservation of his writings.

- An overview of Aristotelian natural philosophy and cosmology

Readings: [HNP] 27-51; Aristotle, excerpt from *On the Heavens* [D]

Week 6: *Natural Philosophy in the Middle Ages*

10/2, 4
- The medieval university

- The impact of Aristotelian natural philosophy in the early 13th century; William of Auvergne (ca. 1180-1249)

- University lectures on natural philosophy

- The classification of the sciences and the subject of natural philosophy

- The occult sciences and natural philosophy

**Readings:** [HNP] 143-178

**Week 7:** The Transformation of Medieval Natural Philosophy from the Early Modern Period to the End of the Nineteenth Century

- The fate of medieval natural philosophy during the sixteenth and seventeenth centuries.

- The new natural philosophy of the seventeenth century: The Transformation of Natural Philosophy; introduction to the ideas of Copernicus, Tyco, Kepler, Galileo; Newton; experiments; the dissemination of scientific knowledge; the forms of literature in the new natural philosophy; scientific societies and journals; natural magic; natural philosophy and religion.

**Readings:** [HNP] 274-302

**Mid-term exam:** Take-home exam prompt distributed in class on 10/9. It is due at the beginning of class on 10/23. It will cover all material through Week 7.

**Week 8:** The Transformation of Medieval Natural Philosophy from the Early Modern Period to the End of the Nineteenth Century (continued)

- The relations between natural philosophy and science in the seventeenth and nineteenth centuries; the medieval background; Francis Bacon: Natural philosophy is "The Great Mother of the Sciences"

- The revolution in natural philosophy from the middle ages to the nineteenth century

- Isaac Newton

- Natural philosophy as a synonym for physics and science in the 19th century

- The continuity of history and the problem of names and terminology

- Thesis: “Although the exact sciences and natural philosophy were largely distinct from one another in the late Middle Ages, the horizons of each began to expand as they gradually came together. The fusion manifested itself bilaterally: natural philosophy influenced the exact sciences to seek the physical causes of relevant phenomena, and thereby broaden the scope of their activities; as this occurred, natural philosophy was inevitably mathematized and its scope expanded. By this process, natural philosophy was the basic instrument in the development of our many modern sciences.” (Grant, 319)

**Readings:** [HNP] 303-322; Galileo, "Corpuscularianism" from *The Assayer* (1623) [D]; Boyle, "Of the Excellency and Grounds of the Corpuscular or Mechanical Philosophy" (1674) [D]
Week 9: *From Scientific Revolution to Scientific World View*
10/23, 25

- Thesis: Empirical discoveries are inspired by phenomena deemed ‘anomalous’ by the current conventional conceptual framework. When conventional scientific theories are incapable of accommodating these new empirical discoveries, new scientific theories emerge. When these new theories cannot be coherently bridged to existing theories (and the conventional worldview informed by these theories), a scientific revolution can ensue—often bringing with it an eventual change in the conventional worldview.

- Throughout the remainder of this course, we will investigate this thesis by examining the evolution of today’s physical sciences (and today’s ‘scientific’ worldview) from this point in history forward.

**Readings:** Kuhn [SSR], Chapters 6-10 (pp. 52-135)

**Mid-term exam:** Due (printed, stapled) at the beginning of class on 10/23.

Week 10: *The Rise of the Mechanical View*
10/30, 11/1

- Galileo and Newton

- The notion of philosophical generalizations founded on empirical results; e.g., “in mechanics the future path of a moving body can be predicted and its past disclosed if its present condition and the forces acting upon it are known. Thus, for example, the future paths of all planets can be foreseen. The active forces are Newton’s gravitational forces depending on the distance alone.” (Einstein & Infeld, p. 67)

- “The great results of classical mechanics suggest that the mechanical view can be consistently applied to all branches of physics, that all phenomena can be explained by the action of forces representing either attraction or repulsion, depending only upon distance and acting between unchangeable particles.” (Einstein & Infeld, p. 67)

- The kinetic theory of matter exemplifies the above in its explication of the phenomenon of heat, ultimately leading to a new understandings of the structure of matter.

**Readings:** [EP] 3-70

Week 11: *The Decline of the Mechanical View*
11/6, 8

- How electricity and magnetism undermine the mechanistic-materialistic paradigm.

- Attempts to characterize light as a corpuscular substance; Newton and the riddle of color; Huygens and the wave model of light.

- Ether and the mechanical view: “Waves spreading in a medium consisting of particles, with mechanical forces acting between them, are certainly a mechanical concept. But what is the medium through which light spreads and what are its mechanical properties? There is no hope of reducing the optical phenomena to the mechanical ones before this question is answered. But the difficulties in solving this problem are so great that we have to give it up and thus give up the mechanical views as well.” (Einstein & Infeld, p. 126)

**Readings:** [EP] 71-128

**Paper:** The topic of the 6-8 page essay will be assigned in class on 11/6. It is due at the beginning of class on **Tuesday 11/20.**
Week 12: The Field – A Paradigm Shift in Physics
11/13, 15

- A new concept appears in physics, the most important invention since Newton’s time: the field.

- “It needed great scientific imagination to realize that it is not the charges nor the particles but the field in the space between the charges and the particles which is essential for the description of physical phenomena.” (Einstein & Infeld, p. 259)

Readings: [EP] 129-185

Week 13: Relativity – The Paradigm Shifts Further
11/20

- The theory of relativity arises from the field problems explored last week. The contradictions and inconsistencies of the old theories force us to ascribe new properties to the time-space continuum, to the scene of all events in our physical world.

- The special theory of relativity: Based on two assumptions: 1. physical laws are the same in all co-ordinate systems moving uniformly, relative to each other; 2. the velocity of light always has the same value. From these assumptions, the theory allows for two key deductions: 1. changes in the lengths and rhythms of moving rods and clocks—changes that defy classical convention and that have been empirically confirmed; 2. the combination of the conservation laws of mass and energy, such that mass is now understood as energy, and energy is understood as having mass. Thus, the theory of relativity entails a revolutionary revision of the classical laws of mechanics.

- The general theory of relativity: Extends the special theory beyond the restriction of inertial (non-accelerating) coordinate systems. The general theory of relativity addresses previous deficiencies in the understanding of gravity, formulating new structure laws for the gravitational field. It also rehabilitates the classical intuition that geometry (and mathematical structure in general) is not merely an epistemic construct of the human mind, but rather an ontological (physically significant) feature of the world itself.

Readings: [EP] 186-262

Paper: The essay assigned on 11/6 is due in class on Tuesday 11/20.

11/22 THANKSGIVING HOLIDAY

Week 14: Quantum Theory and the Crisis for Deterministic, Mechanistic Materialism: The Emergence of a New World View
11/27, 29

- Continuity and discontinuity; elementary quanta of matter and electricity; the quanta of light.

- Quantum indeterminacy; attempts to bridge quantum theory to conventional deterministic physics (and more broadly, the conventional deterministic, mechanistic-materialist worldview); the incompatibility of quantum theory and relativity theory; the failure to reduce quantum theory to conventional deterministic physics.

- The crisis in physics, and the rise of exotic interpretations that undermine classical logic (and the implications for the scientific method, which depends upon classical logic.)

from *Foundations of Relational Realism: A Topological Approach to Quantum Mechanics and the Philosophy of Nature* [D] (29-51)

Week 15: *Quantum Theory and the Crisis for Deterministic, Mechanistic Materialism: The Emergence of a New World View* (continued)

- A new understanding of substance and logic in quantum mechanics.

- A potential new paradigm shift in physics: Understanding physical systems as histories of quantum events.


https://www.sciencenews.org/blog/context/quantum-mysteries-dissolve-if-possibilities-are-realities

**Final Exam Prompt:** Distributed in class on 12/4.

Final Exam: TBA